Syllabus for Continuum Mechanics for Soft Tissues

Introduction

Continuum Mechanics for Soft Tissues is an introductory course in the analysis of the kinematic and mechanical behavior of materials modeled on the continuum assumption. The course will focus on the tools necessary to model soft tissues, including the essential mathematics, stress principles, kinematics of deformation and motion, elasticity, and viscoelasticity.

Course Rationale

The course is appropriate for anyone wishing to learn continuum mechanics, even those outside the field of biomechanics. The emphasis for applications will be on soft tissues, but the student will develop general skills for continuum stress and strain analysis.

Class Meeting Times and Activities

Tuesdays and Thursdays, 9:30-10:50 AM, Learned Hall, Room 3038

The coursework will consist of readings, lectures, in-class group and collaborative learning exercises, homework assignments, and exams.

Course Goals

After active participation in this course and an effort to learn the material, students will be able to:

1. Describe kinematics and deformation using Lagrangian and Euler descriptions.

2. Develop constitutive equations based on fundamental laws and equations.

3. Become a skilled user of advanced design tools such as nonlinear, explicit finite elements.

4. Apply linear elasticity to solve for stress distributions.

5. Apply nonlinear elasticity (based on a molecular and phenomenological development) to rubber-like materials.

6. Use linear (and quasi-linear) viscoelasticity to solve for stresses in modern polymers and soft tissues.

Course Materials

One primary text will be used in this course:

Continuum Mechanics for Engineers, 2nd Edition, by G. Thomas Mase and George E. Mase (1999)

A secondary (supplemental) text will also be reference in the latter part of this course:

Biomechanics: Mechanical Properties of Living Tissues, 2nd Edition, by Y.C. Fung (1993)

Course Outline

Day 1:

Course Introduction ("prerequisites"), Policies,
Introduction to Blackboard Software,
Essential Mathematics (Chapter 1)

Weeks 2-3: Essential Mathematics (Chapter 1)

Scalars, Vectors, Tensors, Symbolic and Indicial Notation
Matrices & Determinants, Tensor Transformations, Eigenvalues and Eigenvectors
Tensor Fields & Tensor Calculus, Integral Theorems of Gauss and Stokes

Weeks 3-5: Stress Principles

Body/Surface Forces & Density, Cauchy Stress Principle, The Stress Tensor
Force and Moment Equilibrium, Stress Tensor Symmetry, Stress Transformation Laws
Principle Stresses & Directions, Maximum & Minimum Stresses, Mohr's Circle for Stress
Plane Stress, Deviator and Spherical Stress, Octahedral Shear Stress

Weeks 5-7: Kinematics of Deformation & Motion

Particles and Configurations, Deformation and Motion, Material and Spatial Coordinates
Lagrangian & Eulerian Descriptions, Displacement Fields, Material Derivatives
Deformation Gradients, Finite Strain Tensors, Infinitesimal Deformation Theory
Stretch Ratios, Rotation & Stretch Tensors, Velocity Gradient, Rate of Deformation
Vorticity, Material Derivatives of Line Elements, Areas and Volumes

Weeks 8-9: Fundamental Laws and Equations

Balance Laws, Field and Constitutive Equations, Material Derivatives of Line, Surface, and Volume Integrals
Conservation of Mass and Continuity Equation, Linear Momentum Principle and Equations of Motion
Piola-Kirchhoff Stress Tensors, Lagrangian Equations of Motion, Angular Momentum Principle
Conservation of Energy, Entropy, Material Restrictions due to 2^{nd} Law, Invariance
Constitutive Equation Restrictions Due to Invariance, Constitutive Equations

Week 10: Nonlinear Elasticity

Molecular Approach to Rubber, Strain Energy Theory
Specific Forms of Strain Energy, Neo-Hookean Material

Week 11-12: Linear Viscoelasticity

Viscoelastic Constitutive Equations, One-Dimensional Theory/Models, Creep and Relaxation
Superposition Principle, Heredity Integrals, Harmonic Loadings
Complex Modulus and Compliance, Three-Dimensional Problems, Correspondence Principle

Week 13-15: Quasi-Linear Viscoelasticity

Quasi-Linear Viscoelastic Constitutive Equations, Applications to soft tissues

Course Requirements and Grading

The grading scheme is subject to change. Current plans are as follows:

Homework	(20%)
Poster Presentation	(10%)
Midterm 1	(20%)
Midterm 2	(20%)
Final Exam	(30%)

Homework is due at the beginning of class time on the due date. Homework will be accepted up to 1 week late, with a 10% reduction in score for each day late. For instance a homework turned in 3 days late would be graded normally, but the final score would be reduced by 30 percent. Problems for which the solution has been discussed in class after the due date will receive a zero score, but other problems will be scored normally under the 1 week late homework policy.

Exam dates are provided in the detailed schedule handed out in class and available from the course webpage. Anyone missing the exam (except due to emergency) without informing the instructor of a conflict at least one week prior to the exam will receive a zero score for the exam. By contacting the instructor in advance, arrangements can be made for an alternate exam day and/or time.

Attendance is not required, but poor attendance will almost certainly result in a poor grade in the course.

Course Policies (Academic Integrity)

Students in this course will be expected to comply with the University of Kansas Policy on Academic Integrity. Any student suspected of violating this obligation for any reason during the semester will be required to participate in the procedural process, initiated at the instructor level, as outlined in the University Guidelines on Academic Integrity. This may include, but is not limited to, the confiscation of the examination of any individual suspected of violating University Policy. Furthermore, no student may bring any unauthorized materials to an examination, including dictionaries and programmable calculators.

Course Policies (Disabilities)

Any student at the University of Kansas who has a disability that may prevent him/her from fully demonstrating his/her abilities should contact the instructor and the office of Services for Students with Disabilities (SSD) as soon as possible, so we can discuss accomodations necessary to ensure full participation in this course and your college experience.

Note that students must self-identify to SSD and the faculty, the SSD staff will collect documentation and evaluate eligibility. SSD will provide a letter too notify faculty of appropriate accomodations. Faculty have no obligation to provide accomodations without a letter from SSD, and there is no requirement for retroactive consideration. It is the student's responsibility to follow up with faculty on implementation of the accomodations in the SSD letter.